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4as Jornadas de Proteção Civil

INSTITUTO POLITÉCNICO DE COIMBRA

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LIVRO DE RESUMOS

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PREFÁCIO

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Deixo, por isso, uma palavra de reconhecimento e agradecimento às Comissões Organizadora, Executiva e Científica, bem como a todos os participantes — investigadores, profissionais, estudantes e agentes da proteção civil — que tornam possível esta edição. Que este encontro inspire novas ideias, parcerias e projetos, continuando a honrar o legado iniciado há vinte anos.

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9AS JORNADAS DE SEGURANÇA AOS INCÊNDIOS URBANOS (9JORNINC)

4AS JORNADAS DE PROTEÇÃO CIVIL (4JORPROCIV)

ACCURATE 3D NUMERICAL MODELS FOR THE FIRE PERFORMANCE ON LSF PARTITION WALLS UNDER DIFFERENT FIRE SCENARIOS

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ABSTRACT

The present study proposes a numerical model analysis of the fire performance of non load-bearing Light Steel Frame (LSF) walls under fire. Assessments were conducted under ISO 834 and HYDROCARBON fire scenarios, including the numerical validation of medium-scale experimental fire resistance tests. Comparison between numerical and experimental results used three different computational solution methods for LSF walls without cavity insulation. The hybrid method (solution method 1) considers convection and radiation in the cavity region, using the experimental cavity temperature. To predict this temperature, solution method 2 uses interface elements for radiation heat transfer, while solution method 3 considers both heat transfer modes, radiation and convection, in the cavity region. This comprehensive analysis used the Root Mean Square Error (RMSE) to compare the temperature evolution at different locations on the wall section at specific time increments, and the relative error to the fire resistance.

1. INTRODUCTION

The growing concern about fire safety in buildings is driven by recent accidents and their tragic consequences. These accidents have heightened the importance of evaluating the fire performance of Light Steel Frame (LSF) walls. Figure 1 presents one of the last fire events in Valencia (Spain) in 2024, where fire spread in one hour through the 138 apartments and left at least ten dead people and up to 14 missing people. One can see that the partition walls failed and the LSF were highly deformed, losing all the gypsum layers and protection material.

Figure 1: Fire in a LSF building in Valencia (Spain) (photo from El Pais, Mònica Torres).

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2. MATERIALS, METHODS AND RESULTS

Three different solution methods were applied to model Specimens “S9” and “S13”, following the experimental tests developed in 2020 (Chen et al., 2020). Recent models have been developed (Piloto et al., 2022) (Piloto et al., 2023), assuming the convection heat transfer coefficient in the cavity region by average coefficients applied to exposed and unexposed surfaces.

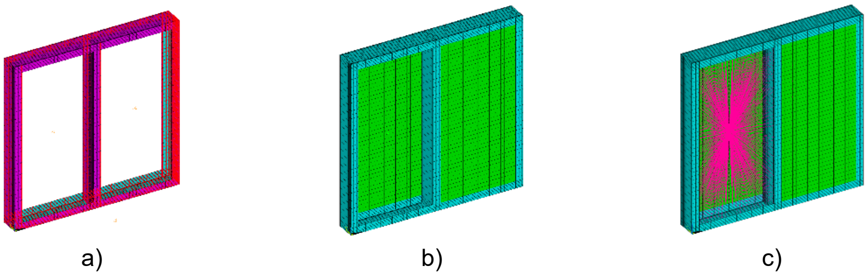

Figure 2: 3D computational models: a) method 1; b) method 2; c) method 3.

The hybrid method (solution 1) presented a lower RMSE, providing a better approximation by considering phenomena such as cracks and material falls during the tests. A parametric study was developed to investigate the thermal effect of the thickness and type of the wall protection layer, as well as the density of the insulation material. The results allowed for the formulation of a new proposal to predict fire resistance for insulation.

KEYWORDS: Fire; Light Steel Frame Walls; Computational Models; Validation.

REFERENCES

Chen, W., Jiang, J., Ye, J., Zhao, Q., Liu, K., & Xu, C. (2020). Thermal behavior of external-insulated cold-formed steel non-load-bearing walls exposed to different fire conditions. Structures, 25(March), 631–645. https://doi.org/10.1016/j.istruc.2020.03.044.

Piloto, P. A. G., Gomes, S., Torres, L., Couto, C., & Vila Real, P. (2023). Accuracy of 2D numerical models towards the prediction of the fire resistance on LSF partition walls. International Journal of Thermal Sciences, 193(March), 108511. https://doi.org/10.1016/j.ijthermalsci.2023.108511.

Piloto, P. A. G., Khetata, M. S., & Ramos-Gavilán, A. B. (2022). Analysis of the critical temperature on load bearing LSF walls under fire. Engineering Structures, 270(July), 114858. https://doi.org/10.1016/j.engstruct.2022.114858.

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SUScita
Sustentabilidade, Cidades
e Inteligência Urbana
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9as Jornadas de Segurança aos Incêndios Urbanos
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Coimbra, 7 de novembro de 2025

ACCURATE 3D NUMERICAL MODELS FOR THE FIRE PERFORMANCE ON LSF PARTITION WALLS UNDER DIFFERENT FIRE SCENARIOS

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ABSTRACT

This study presents the development and validation of advanced 3D numerical models to analyse the fire performance of non-load-bearing Light Steel Frame (LSF) partition walls under different fire scenarios, specifically the standard ISO 834 and HYDROCARBON fire. Medium-scale experimental fire resistance tests from prior research were used for validation, focusing on LSF walls with and without cavity insulation (external composite insulation). Three computational solution methods were compared and used to predict the fire behaviour of LSF walls with a void cavity. The finite element method was employed for transient thermal analysis with temperature-dependent material properties, including adaptations to simulate material degradation such as gypsum board cracking and rock wool melting under HYDROCARBON fire conditions. Hydrocarbon fires reduced fire resistance by an average of 57% compared to ISO 834 fires for cavity-insulated walls, whereas external insulation configurations showed less reduction.

KEYWORDS: Fire; Light Steel Frame; Partition Walls; Computational Models.

1. INTRODUCTION

The growing concern about fire safety in buildings is driven by recent accidents and their tragic consequences in terms of loss of lives and material damage. These accidents have heightened the importance of evaluating the fire performance of Light Steel Frame (LSF) walls.

Although regulations and simulations of the standard ISO 834 fire test are widely used to assess performance under fire conditions, there is a lack of information regarding other fire scenarios. HYDROCARBON fires, usually applied in facilities of oil, gas, and chemical complexes, can also occur in buildings, as evidenced by the attack on the Twin Towers on September 11, 2001 (Kodur, 2003), contributing to the total collapse of the structure (Gravit & Golub, 2018). These events led to in-depth studies of fires under non-conventional conditions.

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The cladding of LSF walls plays a crucial role in optimising thermal insulation. Commonly used materials include plasterboard, calcium silicate boards, oriented strand boards (OSB), and steel sheets (Chen et al., 2020). Their application not only serves as a surface prepared for finishes but also plays a vital role in protecting against direct fire exposure and lateral containment of steel studs, contributing to structural stability (Kesawan & Mahendran, 2018). Additionally, insulation materials such as mineral wool, fibreglass, and cellulose fibre can be employed to improve the acoustic and thermal control of walls due to their low heat transfer characteristics. However, using these materials within the cavity of walls provides lower fire resistance (R) compared to walls with empty cavities (Kodur & Sultan, 2006) (P. Kolarkar & Mahendran, 2012). On the other hand, using insulation between protective layers offers better thermal and fire protection (P. Kolarkar & Mahendran, 2012), because external insulation results in a near uniform temperature distribution over the stud cross-sections, reducing the risk for thermal bowing, and increasing the thermal protection to the LSF walls.

Previous studies (Magarabooshanam et al., 2020) devoted special attention to the thermal analysis performance of LSF walls when used as partitions. These authors conducted full-scale experimental tests to investigate the fire resistance of LSF walls using single, double, and alternate studs, considering different cavity depths. The results highlighted that two layers of gypsum coating and a wider cavity exhibited greater fire resistance. These results are in agreement with previous experimental investigation developed at IPB (Alves et al., 2021), when testing double stud LSF walls. This investigation also presented highly accurate computational models and a new simplified design method.

Only a small number of investigations have been dedicated to CFS walls exposed to HYDROCARBON fires (Chen et al., 2020). This study also includes a comparison with standard fire ISO834 (ISO, 1999), external fire and realistic fire, using an external composite insulation strategy with mineral wool (60 kg/m^3). This new insulation strategy was compared with the same LSF using full cavity insulation, using the same mineral wool (Chen et al., 2019). Both studies (Chen et al., 2020), (Chen et al., 2019) will be used for the numerical validation of the models developed in this manuscript.

To improve the knowledge and the computational models, the initial research developed at IPB, (Piloto, Khetata, & Gavilán., 2017) contributed significantly to the field by developing an accurate numerical model based on thermal and fluid analysis with air-structure interaction. This research increased by introducing a simplified method, (Piloto, Khetata, & Gavilán, 2017), based on one-dimensional heat flow algebraic equations, considering different thermal flow paths, across the steel stud. These results were compared with a 2D solid finite element analysis, with a very good agreement during time and a maximum relative difference in fire resistance up to 5%. In the same year, (M. Khetata et al., 2017) developed a numerical validation using finite cells, with air-structure interaction, and finite elements in solid parts to determine the thermal performance of four experimental results developed by (P. N. Kolarkar, 2010). This study also included a parametric analysis to consider the effect of the steel thickness, the effect of the cavity thickness, and the number and thickness of the gypsum boards.

(Piloto et al., 2018) presented four experimental tests with numerical validation and a parametric study for load-bearing resistance. The fire resistance is usually provided by one or more layers of materials and or by the cavity insulation. This investigation evaluates the fire resistance of the load-bearing walls, from the point of view of insulation (I) and load-bearing capacity (R). Experimental results obtained from partition walls were used in the numerical model to accurately predict the cracking, falling off and the ignition of combustible material. The 3D numerical model was validated under the same fire conditions. The load-bearing capacity was determined using this hybrid model. This model can predict an accurate fire resistance for any load level, taking into account the brittle behaviour of gypsum panels and the ignition of combustible materials. The load-bearing decreases with the increase in the load level. A new formula was presented to determine the critical average temperature of the LSF. More experimental results were developed with validation using 2D numerical models (S. M. Khetata et al., 2020). Seven small-scale specimens were tested to define the fire resistance of non-load bearing LSF walls made with different materials, including external composite layers and cavity insulated partition walls using rockwool and superwool. All tests were validated using 2D numerical models, based on the finite-element method, the finite-volume method and the hybrid finite-element method. It was concluded that the fire resistance increases with the number of studs and also with the thickness of the protection layers. The hybrid finite-element solution method seems to be the best approximation model to predict fire resistance. Following the previous investigation, (Piloto et al., 2022) presented the simulation results of composite LSF walls in reduced scale and full scale, based on variable load levels (20 to 80%). The numerical model used the hybrid model approximation to accurately determine the temperature field under fire conditions. The insulation ability to sustain fire usually increases with the number of studs and with the application of insulation material in the cavity region. The ability to sustain the load under fire also increases with the number of studs, especially for higher load levels. A new proposal was presented for the critical temperature of the LSF, based on the maximum temperature of the LSF during the fire, allowing the calculation of the critical temperature, based on the load level of the specimen. This relation can predict the fire resistance time, based on the preliminary thermal analysis of the specimen. The reduced scale specimens present higher critical temperatures when compared to the full scale specimens, due to the typical failure mode (local modes for the reduced scale and global modes for the large scale). A more detailed analysis regarding the cavity region was developed by the same research group (Piloto et al., 2023), analysing three different computational methods to compare the fire performance of LSF walls with void cavities.

External wall are also being investigated (Torres et al., 2023), focusing on the fire affecting external walls from the external and internal side. The results show that the temperature evolution is slower when the fire is impacting the outer side of the wall but, in these cases, the recommended critical temperature of 350 ºC is reached earlier in the steel profiles, but this conclusion is materially dependent.

The performance of CFS stud walls under compression loading, subjected to one-sided and double-sided fire exposure, has also been investigated (Hassoune et al., 2025). The results demonstrate the significant impact of the double-sided fire exposure on CFS walls performance, reducing the fire resistance by 41 % and 50 % for CFS thicknesses of 1.15 mm and 1.5 mm, respectively, compared to one-sided fire exposure.

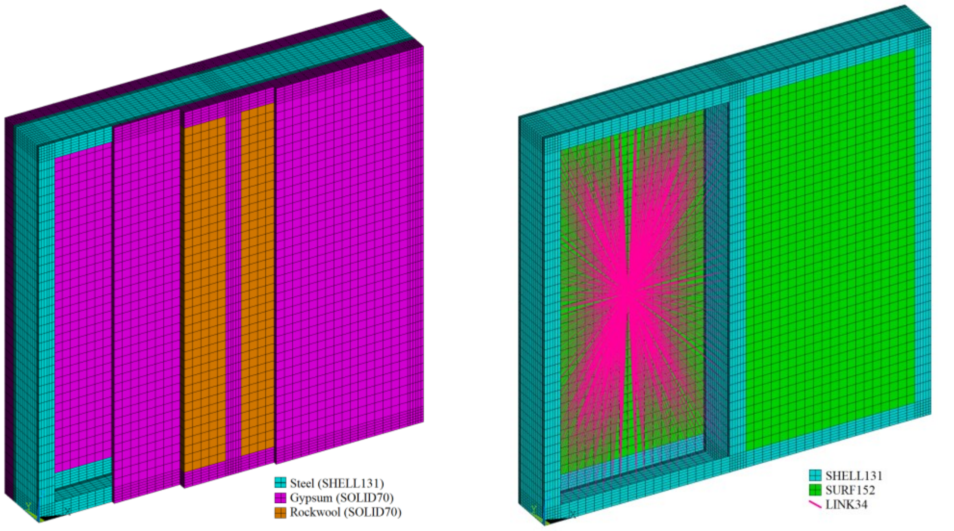
This current investigation aims to enhance knowledge in the analysis of partition walls subjected to standard and HYDROCARBON fires. Unlike the standard fire curve, which demonstrates a gradual increase over time, hydrocarbon fires exhibit a rapid increase in temperature accompanied by a flame shock wave in the LSF structures and building materials (Gravit & Golub, 2018). The specific curve for this fire reaches approximately 1100°C in about half an hour, maintaining a constant temperature from that point on. The high temperatures of HYDROCARBON fires are typically used for hazard assessments in the offshore industry, petrochemical plants, road and railway tunnels, and ships,

2. COMPUTATIONAL MODEL

This section outlines the methodology, focusing on the analysis with finite element models. These models were conceived based on LSF partition walls used in experimental tests conducted by other researchers (Chen et al., 2019), (Chen et al., 2020). The adopted approach incorporates various methods to assess the fire resistance of non-load-bearing LSF walls, considering both standard ISO834 and HYDROCARBON fire conditions. The simulations covered fire test conditions, using transient thermal analysis with temperature-dependent material properties. Validation of the results will be conducted through a comparison with experimental tests.

Heat transfer analysis through the finite element method was used to solve the 3D second-order partial differential equation, using the weighted residual method and Galerkin approximation to transform into a set of nonlinear algebraic equations. This system is solved using incremental and iterative numerical methods. The temperature field T is determined by solving the heat conservation equation inside the solid parts, through the discretisation of the domain using a finite element mesh as illustrated in Figure 1. The material properties are temperature dependent, and the solution method is incremental and iterative, using a time increment of 60 s, with the possibility to reduce to 1 s, if required. The convergence criterion was based on heat flow, with a tolerance of 10^{-3} and a minimum reference value of 10^{-6} W.

Three distinct numerical solution methods were used for a more accurate simulation of the fire performance of LSF walls with external insulation. The hybrid method (solution method 1) incorporates convection and radiation in the cavity region based on the previously measured experimental cavity temperature (bulk temperature is introduced as a boundary condition). The second method (solution method 2) considers interface elements for heat transfer exclusively by radiation, while the third method (solution method 3) involves heat transfer by radiation and convection in the cavity region. Additionally, a finite element model was developed to simulate the fire test on internally insulated LSF walls. Modifications to the thermal properties of the mineral wool insulation were implemented to simulate the material degradation during the test under hydrocarbon fire conditions. These adaptations aim to bring the numerical results closer to the experimental results.



a) LSF model with composite sheeting boards (details solution method 1, 2 and 3).

b) Interface finite elements for convection and radiation (details for solution method 3).

Figure 1: Finite element mesh for the model with void cavity.

The boundary conditions are defined in the exposed and unexposed sides of the LSF walls. Depending on the model, the boundary conditions should also be applied to the cavity region. The exposed surface is submitted to radiation and convection, while convection is assumed in the unexposed surface with an appropriate convection coefficient to consider the radiation effect. The cavity region is also submitted to convection and radiation, but using average convection coefficients between the exposed and unexposed surfaces.

To simulate heat transfer that occurs when LSF walls are subjected to standard ISO834 fire and HYDROCARBON boundary conditions, the following parameters were applied: For the validation models, an initial temperature of 5 ºC was set at all nodes, based on conducted experimental tests (Chen et al., 2019) (Chen et al., 2020). Subsequently, conditions were applied for the exposed fire side (FS), for the unexposed side (UNEX), and lastly, for the cavity region (if necessary). According to EN 1991-1-2 (CEN, 2002), different values should be used for the convective heat transfer coefficient for the exposed fire side. For the fire scenario using the standard ISO834, a convective heat transfer coefficient α_c of 25 W/m^{2}K was used. For the HYDROCARBON fire curve, a convective heat transfer coefficient α_c of 50 W/m^{2}K. The boundary condition for the unexposed side used a convective heat transfer coefficient α_c of 9 W/m^{2}K, assuming it encompasses the effects of radiation heat transfer.

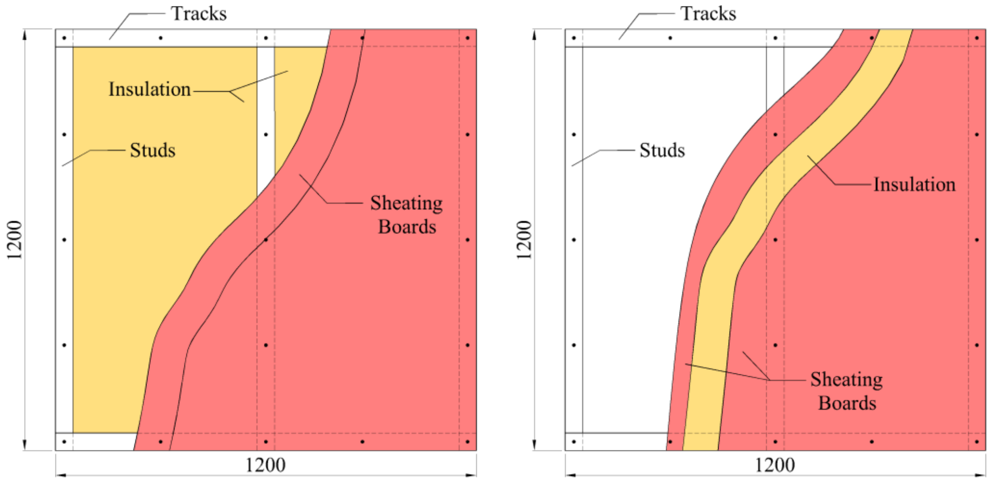
Different boundary conditions were applied to the cavity region depending on the solution method, considering that in LSF walls with empty cavities (external insulation), heat transfer occurs through convection and radiation. When using convection inside the wall cavity, one can assume an average value between the exposed fire side and the unexposed side, using 17 W/m^{2}K for Standard ISO834 and 29.5 W/m^{2}K for the HYDROCARBON fire scenario (Piloto et al., 2018).

The finite element mesh includes different element types. The finite element SOLID 70 (ANSYS) is a 3D element used to model protection materials (gypsum and mineral wool), has eight nodes with a single degree of freedom per node (temperature), uses linear interpolating functions and the full Gauss integration method (2x2x2). The finite element SHELL 131 (ANSYS) is a 3D layered shell element used to model the LSF structure, having in-plane and through-thickness thermal conduction capability. The element has four nodes with up to 32 temperature degrees of freedom at each node, uses linear interpolation functions with a full Gauss integration scheme (2x2). The interpolation through thickness uses 5 integration Gauss points.

For the case of void cavities in LSF walls, the finite element LINK34 (ANSYS) simulates uniaxial thermal convection between nodes. The convective heat transfer rate is determined based on the film coefficient, convection area, and possible empirical coefficients (not used here). This element also has no interpolating function or numerical integration, and uses a direct formula to determine the heat flow by convection. The finite element SURF 152 (ANSYS) simulates the radiation from inside the cavity region (surface to node). It may be overlaid onto the face of any 3D thermal element (SOLID 70). The element uses linear interpolating functions and full in-plane Gauss integration (2x2).

2.1 Specimens used for validation

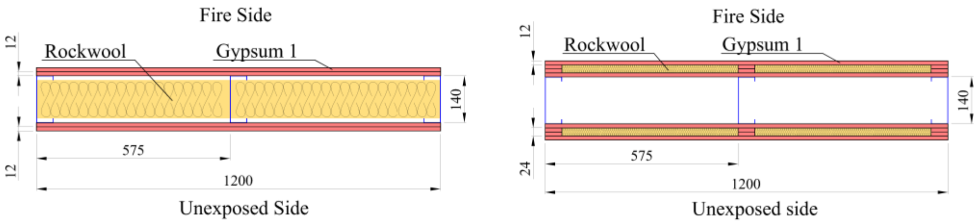
The non load-bearing LSF walls used to validate the models include the test specimens “S1” and "S5," developed in 2019 (Chen et al., 2019), and the specimens “S9” and “S13”, developed in 2020 (Chen et al., 2020). The medium-scale LSF wall specimens, used in both studies, were manufactured with a width and height of 1.2x1.2 m, as depicted in Figure 2. The LSF was constructed by assembling three C140 studs (140×50×13×1.2 mm) every 600 mm and two unlipped U142 tracks (142×50×1.2 mm). The steel studs and tracks were made from a galvanised steel sheet (Q345) with a nominal wall thickness of 1.2 mm and a nominal yield strength of 345 MPa. The LSF was covered with two layers of gypsum board on both sides (1200×1200×12 mm), each with a thickness of 12 mm.



a) Specimens S1 and S5. b) Specimens S9 and S13.

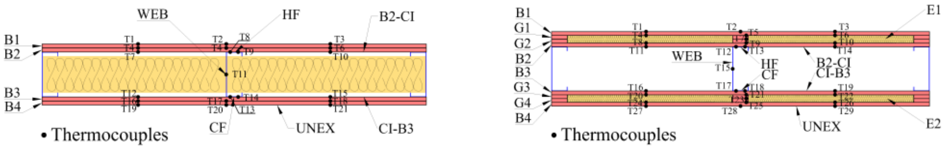
Figure 2: LSF wall with insulated cavity and external insulated wall (composite layers).

The cross-section configuration is depicted in Figure 3, where one can see the different insulation methods (inside cavity and outside cavity) and the position of the thermocouples. To monitor the thermal response of the LSF walls during the fire experiments, a total of 21 and 29 type K thermocouples were used at mid-height sections of each specimen. For the LSF wall specimens “S1” and "S5," a 150 mm thick rockwool insulation (density of 60 kg/m^3) was used as insulation in the cavity of the steel frames. For specimens “S9” and “S13”, a 24 mm thick rockwool insulation (density of 60 kg/m^3) was used as external insulation between the gypsum boards. Simultaneously, two layers of gypsum board strips are placed directly on the line of the steel studs to prevent compression deformations and irregular joints on the wall surfaces.



a) Insulation inside the cavity. Specimens “S1” and “S5”.

b) Insulation between plates (composite external insulation). Specimens “S9” and “S13”.



c) Thermocouple position. Specimens “S1” and “S5”.

d) Thermocouple position. Specimens “S9” and “S13”.

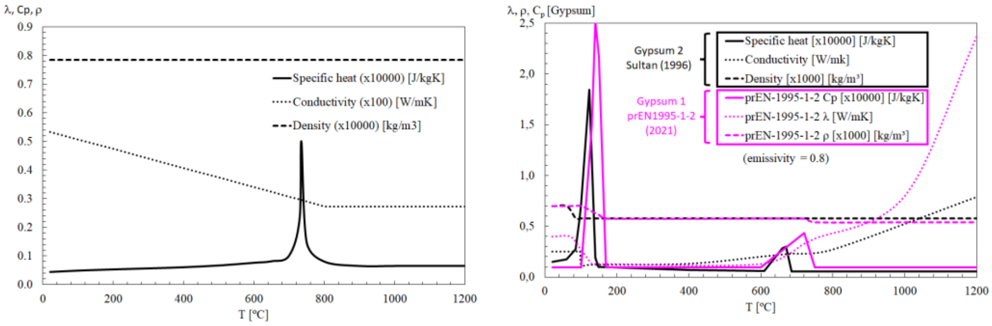
Figure 3: LSF walls under investigation (Chen et al., 2019), (Chen et al., 2020).

For the validation of void cavities with external insulation in LSF walls, three different solution methods were used. The solution Method 1 employs a hybrid finite element approach to simulate heat transfer through radiation and convection in the cavity region. This model is based on the cavity temperature behaviour derived from previous experiments. The cavity temperature (bulk temperature) is determined as the average between the inner faces in contact with the cavity, the most exposed (hot) layer, and the least exposed (cold) layer. This method was applied to model Specimens “S9” and “S13”, as per the conducted experimental test (Chen et al., 2020). The application of convection and radiation should cover the surfaces in contact with the cavity, including the internal surfaces of the studs and the internal surfaces of the gypsum boards. Therefore, the boundary conditions adopted for the cavity region, when the models are subjected to the standard ISO834 fire, include a convection coefficient of 17 W/m^{2}K. For the models subjected to the HYDROCARBON fire, a convection coefficient of 29.5 W/m^{2}K. Both models were subjected to the radiation boundary condition inside the cavity region with a flame emissivity value of 1. Additionally, the final time for the simulations was defined to be 185 min and 91 min for specimens S9 and S13, respectively. The solution method 2 only considers radiation inside the cavity region, using the interface finite element SURF 152. Unlike solution method 1, the solution methods 2 and 3 do not rely on experimental data to input boundary conditions, thus allowing to increase the simulation time. The solution method 3 is similar to solution method 2, but includes additional boundary conditions for convection heat flow. This method uses the same previous finite element SURF 152. Additionally, it includes the finite element LINK 34 to impose a convection boundary in the cavity region. The LINK 34 element facilitates simulating thermal convection between the nodes of the internal areas of the plasterboard in contact with the cavity and the node inserted at the centre of this region, as shown in Figure 1. Finally, higher simulation times were used, as in solution method 2, to reach the fire resistance criteria.

The simulation model used to validate Specimens S1 and S5, does not require interface finite elements. However, during the comparison of numerical results with experimental results, there was a need to adjust the model to enhance the accuracy of the results. There is a physical limitation to simulate these specimens, because thermal degradation is difficult to predict. Thus, adjustments were made to the thermal properties of the mineral wool, aiming for better agreement with experimental results, reflecting the increase in heat transfer associated with these phenomena. After each implemented modification, the error (RMSE) was calculated for each layer of the LSF wall. To select the most appropriate property modification, the criteria adopted were the lowest average RMSE and the lowest RMSE in the layer not exposed to fire, as the latter is used to determine the fire resistance time by insulation (I) of LSF walls.

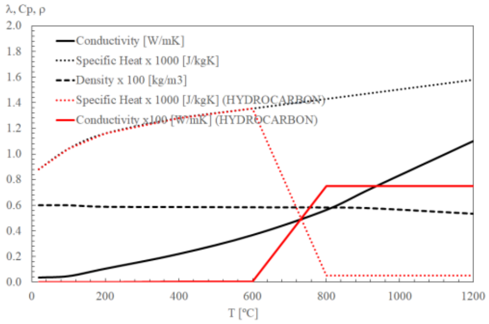
2.2 Thermal properties

The accuracy and reliability of any numerical modelling are directly related to the correct definition of the properties of the materials involved. In the context of simulating LSF walls, different materials were used, each contributing in a unique way to the system's integrity. It is important to note that the properties of these materials have a significant impact on the overall performance of LSF walls. To ensure accurate simulations, the thermal properties of the materials used in the models (specimens) were obtained from established standards EN1993-1-2 (CEN, 2005), the next generation of prEN 1995-1-2 (CEN, 2023) as well as through experimental studies (Sultan, 1996). These properties include thermal conductivity, specific heat, density, and material emissivity, all of which are temperature-dependent and critical to determine the fire performance of LSF walls. Figure 4 illustrates the specific heat of carbon steel, thermal conductivity, and density, which remains at the value of 7850 kg/m^3. The emissivity of carbon steel is equal to 0.7. Two distinct varieties of gypsum plasterboard were used, namely Gypsum 1 defined by prEN 1995-1-2 (CEN, 2023) and Gypsum 2 defined by (Sultan, 1996). Gypsum 1 was selected to validate the numerical models with the experimental results, see Figure 4. The material Rockwool is approximated by the mineral wool thermal properties defined by prEN 1995-1-2 (CEN, 2023), as depicted in Figure 4. The material density 60 kg/m^3, was obtained from the experimental tests (Chen et al., 2019) (Chen et al., 2020). The emissivity was assumed to be 0.8.



a) Steel

b) Gypsum plasterboards



c) Mineral wool (60 kg/m^3).

Figure 4: Thermal properties used for the material models.

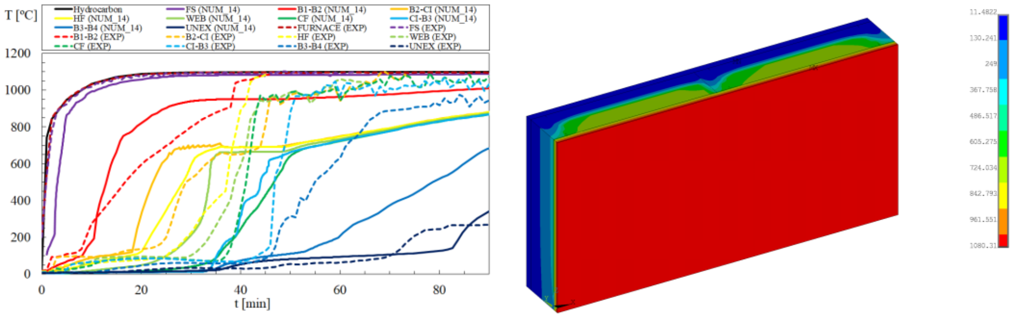
To increase the accuracy of the models, the mineral wool thermal material properties were modified for the case of using HYDROCARBON fire, see Figure 4.

2.3 Validation of the computational model

The temperature evolution over time across all layers of the LSF walls was recorded by the thermocouples installed in the experimental tests, as shown in Figure 3. Therefore, the temperatures in the numerical models were extracted at the same locations as these thermocouples. In this study, a comparison is presented using the RMSE error for the temperature evolution of each component. The relative error (RE) will be used to compare the fire resistance time for insulation (I).

The numerical validation will be presented in the sequence number order of the experimental specimens. Initially, the LSF walls with insulation in the cavity region, referred to as "S1" and "S5" in the experimental test (Chen et al., 2019), will be evaluated based on the average temperature for similar positions. Subsequently, the LSF walls with external insulation, referred to as "S9" and "S13" (Chen et al., 2020), will be examined using the same procedure. Furthermore, this study starts the analysis of Light Steel Framing (LSF) walls exposed to HYDROCARBON fires, followed by walls subjected to the standard fire ISO834.

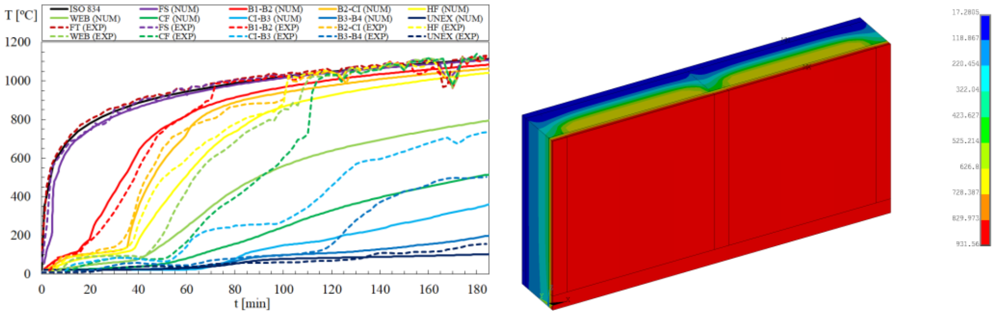
Figure 5 includes the average temperatures of each layer. According to the authors (Chen et al., 2019), the failure of the insulation (I) for Specimen "S5" occurred by the average temperature criterion (140°C above the initial average temperature) after 73 minutes.



a) Numerical results with modified properties. b) Simulation after 30 min of fire exposure.

Figure 5: Experimental and numerical results for Specimen "S5".

The comparison of experimental results with numerical outcomes for the Specimen "S1" is presented in Figure 6. This specimen underwent a 185-minute fire test. According to the authors (Chen et al., 2019), the insulation failure of Specimen "S1" occurred at the maximum temperature criterion (180°C above the initial average temperature).



a) Numerical results using standard Properties. b) Simulation after 60 min of fire exposure.

Figure 6: Experimental and numerical results for Specimen "S1".

Analysing the temperature-time curves obtained from the numerical tests of the two specimens, "S5" and "S1", a discrepancy in results is apparent when gypsum board drops occur, as the numerical models do not assume this modelling event. Additionally, imperfect contact may have occurred between the rockwool insulation and the internal surfaces of the boards and steel profile, creating void spaces in the region, leading to heat transfer through radiation in these small gaps. To address these events, modifications were made to the thermal properties of the materials to simulate such effects as the emergence of cracks, board drops, material combustion, or any other heat release. After processing and extracting data from each implemented modification, the obtained results were compared using RMSE, as shown in Table 1. The best modification option for Specimen "S5" produced the lowest RMSE for the unexposed fire surface (UNEX). One can see that RMSE decreased from 75.9 ºC to 44.3 ºC, corresponding to a better approximation to the experimental results.

Table 1: Comparison of the RMSE values for the numerical results of Specimen “S5” with and without material properties modification.

Thermal properties	FS	B1-B2	B2-CI	HF	WEB	CF	CI-B3	B3-B4	UNEX	Average
standard	111.4	148.5	191.8	181.4	272.7	559.1	581.6	483.2	75.9	289.5
modified	112.5	143.3	204.0	208.1	201.5	222.3	196.6	277.6	44.3	178.9

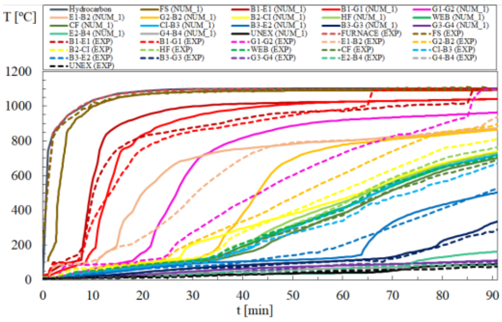
The best material option to evaluate the performance of Specimen “S1” was the starting guess, where standard properties were assumed, possibly due to the partial melting of rockwool insulation, unlike that degradation event in Specimen “S5”. The same modification has been tested, and the comparison is presented in Table 2.

Table 2: Comparison of the RMSE values for the numerical results of Specimen “S1” with and without material properties modification.

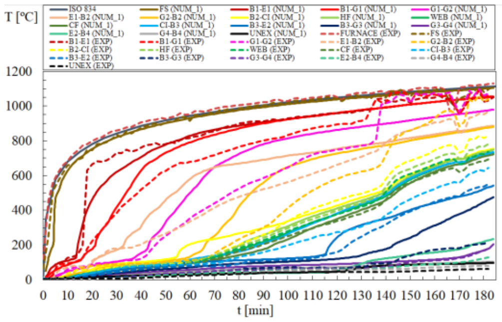
Modification	FS	B1-B2	B2-CI	HF	WEB	CF	CI-B3	B3-B4	UNEX	Average
0	49.9	48.2	43.4	76.3	211.6	308.2	151.8	53.6	11.0	106.0
2	68.5	95.5	189.7	183.1	175.7	162.1	187.2	164.1	180.1	156.2

Therefore, according to the results, when the LSF wall is subjected to standard ISO834 fire, no changes should be made to the material properties. However, for LSF walls subjected to a HYDROCARBON fire curve, modifications should be made. This double strategy is physically understandable because higher material degradation is expected with HYDROCARBON fire.

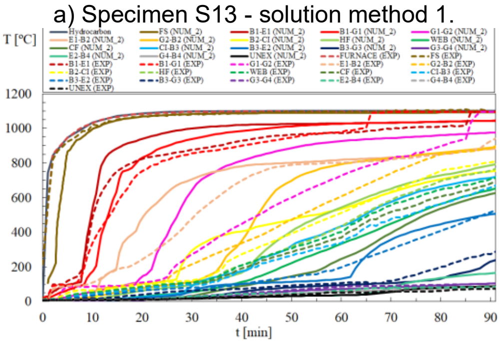
The comparisons between the experimental results of Specimen “S13” and the numerical simulations are presented in Figure 7, using the three solution methods. The average temperatures of each layer from the LSF walls were selected for the graphical comparison. The LSF wall of specimen “S13” was subjected to a HYDROCARBON fire, without insulation in the cavity region. This specimen underwent a 91 minutes fire test and did not reach the insulation fire resistance failure criteria.

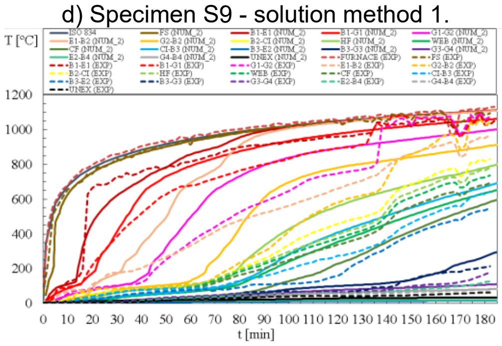


a) Specimen S13 - solution method 1.



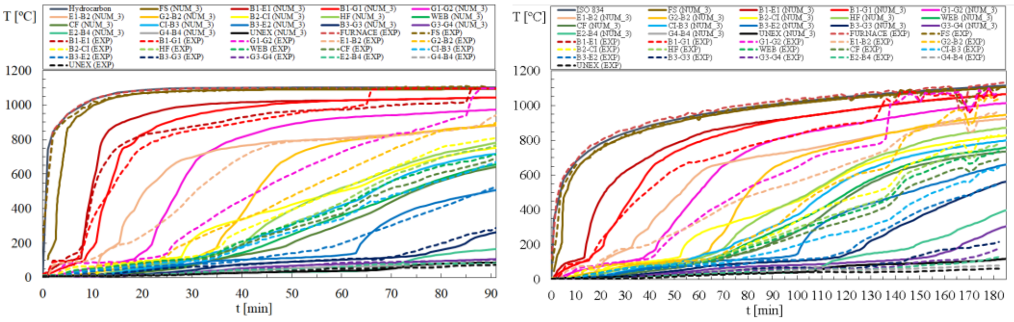
d) Specimen S9 - solution method 1.





b) Specimen S13- solution method 2.

e) Specimen S9 - solution method 2.



c) Specimen S13- solution method 3.

f) Specimen S9 - solution method 3.

Figure 7: Experimental and numerical results for Specimens “S13” and “S9”.

After processing the numerical results, the comparison between the three solution methods was done using RMSE, as shown in the next Table 3 and Table 4.

Table 3: RMSE for the results of Specimen S13 using solution methods 1, 2, and 3.

Specimen S13	Sol. Method 1 RMSE ºC	Sol. Method 2 RMSE ºC	Sol. Method 3 RMSE ºC
FS	96.5	96.4	96.4
B1-E1	79.5	80.3	79.1
B1-G1	72.5	70.4	70.8
G1-G2	216.3	214.3	214.9
E1-B2	113.4	114.9	110.8
G2-B2	103.8	109.9	109.3
B2-CI	49.4	79.9	50.9
HF	21.3	56.1	43.6
WEB	9.9	74.2	57.6
CF	17.6	94.5	56.8
CI-B3	46.4	65.3	55.1
B3-E2	28.2	34.4	29.7
B3-G3	13.1	33.8	18.7
G3-G4	9.6	8.8	4.4
E2-B4	28.6	31.1	30.1
G4-B4	12.8	4.9	8.4
UNEX	8.8	9.4	8.9
Average	54.6	69.3	61.5

The biggest RMSE for the specimen S13 was found to be in the most exposed layers of the composite insulation system. For the other regions, the RMSE is below 100 ºC. Solution method 1 had the smallest RMSE, because it used the addition boundary from experimental tests (cavity temperature) when using the hybrid finite element approach.

Table 4: RMSE for the results of Specimen S9 using solution methods 1, 2, and 3.

Specimen S9	Sol. Method 1 RMSE ºC	Sol. Method 2 RMSE ºC	Sol. Method 3 RMSE ºC
FS	39.8	39.9	39.8
B1-E1	53.4	76.1	53.2
B1-G1	74.6	77.3	76.4
G1-G2	124.8	128.2	126.4
E1-B2	127.2	293.6	142.6
G2-B2	128.8	147.4	156.3
B2-CI	56.3	79.5	108.1
HF	22.5	81	131.7
WEB	14.4	57.4	65.2
CF	14.8	97	74.4
CI-B3	76.6	73.8	182.3
B3-E2	27.5	241.1	107.9
B3-G3	89.6	22.5	145.1
G3-G4	17.9	18.9	41.2
E2-B4	39.7	45	96.5

G4-B4	18.7	5.2	22
UNEX	20.2	14.1	27.8
Average	55.7	88.1	93.9

The biggest RMSE for the specimen S9 was found to be, again, in the most exposed layers of the composite insulation system. For the other regions, the RMSE is below 100 ºC. Solution method 1 had the smallest RMSE, also, for the case of the specimen 9 being subjected to ISO834. The fire test standard EN 1363-1 (CEN, 2020) recommends that, after the initial 10 minutes of the test, the temperature recorded by any thermocouple in the furnace should not deviate by more than 100°C from the corresponding temperature in the standard fire curve.

The fire resistance time for insulation (I) was also compared using the Relative Error (RE). As the fire resistance time for Specimen “S1” of 137 minutes was obtained through portable thermometer measurement, it was possible to identify the temperature across the entire surface, not limited to the thermocouple locations. The fire test was terminated at 185 min of fire exposure, when the average temperature on the unexposed surface reached 156 °C.

The experimental insulation fire resistance for specimen S5, subjected to HYDROCARBON, was 73 min. The simulation using modified thermal properties reached the average temperature criterion after 82.1 min and the maximum temperature criterion at 82.7 min. The RE (12.48 %) for the fire resistance time was reached.

In the case of Specimens “S9” and “S13”, it was not possible to determine the relative error (RE) since the criteria for insulation fire resistance were not achieved in the experimental tests. Moreover, the solution method 1 is limited to the maximum time of fire exposure, due to the need to determine the average cavity temperature. Therefore, Table 5 and Table 6 solely compare the results obtained by each solution method.

Table 5: Comparison of insulation fire resistance for Specimen S13 (t_{fi} (EXP) $\geq$91 min).

Solution	t_{ave}^{T} min	t_{max}^{T} min	t_{fi} min
Sol. Method 1	>91	>91	>91
Sol. Method 2	136	136	136
Sol. Method 3	136	136	136

Table 6: Comparison of insulation fire resistance for Specimen S9 (t_{fi} (EXP) $\geq$185 min).

Solution	t_{ave}^{T} min	t_{max}^{T} min	t_{fi} min
Sol. Method 1	>185	>185	>185
Sol. Method 2	>360	335	335
Sol. Method 3	187	187	187

Solution methods 2 and 3 used for Specimen “S13” exhibit a higher RMSE compared to the solution method 1. This can be explained by the absence of the convection component in the heat flow (solution method 2) and the impossibility of detecting material degradation under fire conditions, even when using effective material properties. This is why one did the adjustment of the thermal properties, especially when using HYDROCARBON fire exposure. Additionally, besides thermal analyses for insulation criteria (I), it is observed that the hybrid method is also more suitable for structural resistance (R) analyses of LSF walls, as it yields better results for temperatures recorded in the studs (HF, WEB, and CF), which are crucial to verify the compression failure modes along the steel studs (Chen et al., 2020) (Kesawan & Mahendran, 2018).

It is essential to highlight that the differences in RMSE were more pronounced in the regions of plasterboards facing the cavity or between the plasterboards. These differences in RMSE results can be explained by the singularities in the behaviour of materials during experiments, as well as in numerical simulations, where perfect contact between materials is assumed.

3. CONCLUSÕES

This manuscript presents a computational model to simulate the effect of different fire scenarios on LSF walls, using different insulation strategies. For the case of void cavities using external insulation, the computation model includes three distinct solution methods, demonstrating good agreement with medium-scale experimental fire resistance tests. The Solution Method 1 (hybrid method), which incorporates convection and radiation in the cavity region using experimental cavity temperatures as boundary conditions, provided the most accurate temperature predictions and the lowest RMSE across various wall layers and for both standard ISO834 and HYDROCARBON fire scenarios. Solution Methods 2 and 3, which rely on interface elements to simulate radiation and convection/radiation in the cavity without experimental temperature input, produced higher RMSE values and less accurate predictions, especially in regions affected by material degradation and cavity effects. Adjustments to effective thermal properties of materials, particularly mineral wool insulation under HYDROCARBON fire exposure, were necessary to simulate degradation phenomena such as gypsum board cracking, fall-off, and insulation melting, improving the model’s predictive capability.

LSF walls subjected to HYDROCARBON fires showed significantly reduced fire resistance times compared to those exposed to the standard ISO 834 fire, with an average reduction of about 57% observed in the studied specimens. The high temperatures and rapid heating rate of HYDROCARBON fires lead to more severe damage and faster degradation of protective materials and insulation.

LSF Walls with insulation placed inside the cavity showed better fire resistance compared to those with external insulation, but the latter with significantly less insulation material (82% reduction in volume). The external insulation exhibited only a 19% reduction in fire resistance under ISO 834 compared to cavity insulation, suggesting practical benefits for specific applications.

The hybrid finite element approach (solution method 1) is recommended for accurate fire resistance prediction of LSF walls, especially when experimental cavity temperature data are available. Numerical models should incorporate material degradation effects, such as gypsum board cracking and melting of insulation, to enhance the fire resistance prediction.

In summary, the research provides a robust and validated computational framework for analysing the fire performance of LSF partition walls under both ISO834 and HYDROCARBON fire conditions. The findings highlight the critical role of gypsum plasterboard thickness, insulation density, and fire scenario in determining fire resistance.

ACKNOWLEDGMENT

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REFERENCES

Alves, M. H., Constantini, G., Ianni, A., Kimura, E. F. A., Meda, A., & Piloto, P. A. G. (2021). Fire performance of non-load-bearing double-stud light steel frame walls: Experimental tests, numerical simulation, and simplified method. *Fire and Materials*, *February*, fam.2969. https://doi.org/10.1002/fam.2969

CEN. (2002). EN 1991-1-2, Eurocode 1: Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire. Em CEN- European Committee for Standardization (Ed.), *CEN- European Committee for Standardization* (p. 59). CEN- European Committee for Standardization.

CEN. (2005). *EN 1993-1-2: Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design*

(CEN- European Committee for Standardization (ed.); CEN-Europ). CEN- European Committee for Standardization.

CEN. (2020). EN 1363-1: Fire resistance tests Part 1 : General Requirements. Em CEN- European Committee for Standardization (Ed.), *CEN* (p. 52). CEN - European Committee for Standardization.

CEN. (2023). pr EN 1995-1.2, Eurocode 5: Design of timber structures - Part 1-2: General - Structural fire design. Em *CEN*. CEN - European Committee for Standardization.

Chen, W., Jiang, J., Ye, J., Zhao, Q., Liu, K., & Xu, C. (2020). Thermal behavior of external-insulated cold-formed steel non-load-bearing walls exposed to different fire conditions. *Structures*, *25*(March), 631–645. https://doi.org/10.1016/j.istruc.2020.03.044

Chen, W., Ye, J., & Zhao, Q. (2019). Thermal performance of non-load-bearing cold-formed steel walls under different design fire conditions. *Thin-Walled Structures*, *143*(January). https://doi.org/10.1016/j.tws.2019.106242

Gravit, M., & Golub, E. (2018). The fire resistant ceiling construction in a hydrocarbon fire. *MATEC Web of Conferences*, *245*, 03004. https://doi.org/10.1051/matecconf/201824503004

Hassoune, M., Kada, A., Menadi, B., Lamri, B., Yessad, O., Piloto, P. A. G., & Jiang, L. (2025). Performance of single and built-up I-shaped cold formed steel stud under double sided walls fire exposure. *Engineering Structures*, *335*(April), 120392. https://doi.org/10.1016/j.engstruct.2025.120392

ISO. (1999). *ISO834-1: Fire-resistance tests - Elements of building construction - Part 1: General requirements* (International Organization for Standardization (ed.); p. 25). International Organization for Standardization.

Kesawan, S., & Mahendran, M. (2018). A Review of Parameters Influencing the Fire Performance of Light Gauge Steel Frame Walls. *Fire Technology*, *54*(1), 3–35. https://doi.org/10.1007/s10694-017-0669-8

Khetata, M., Fernandes, L., Marinho, C., Piloto, P., Gavilán, A., & Razuk., H. (2017). Fire resistance of non-loadbearing light steelframing walls: numerical validation. *XI Portuguese Congress on Steel and Composite Construction – CMM 2017*, 853–862.

Khetata, S. M., Piloto, P. A. G., & Gavilán, A. B. R. (2020). Fire resistance of composite non-load bearing light steel framing walls. *Journal of Fire Sciences*, *38*(2), 136–155. https://doi.org/10.1177/0734904119900931

Kodur, V. K. R. (2003). Role of fire resistance issues in the collapse of the twin towers. Em CIB (Ed.), *CIB-CTBUH International Conference on Tall Buildings* (pp. 111–118). CIB.

Kodur, V. K. R., & Sultan, M. A. (2006). Factors Influencing Fire Resistance of Load-bearing Steel Stud Walls. *Fire Technology*, *42*(1), 5–26. https://doi.org/10.1007/s10694-005-3730-y

Kolarkar, P., & Mahendran, M. (2012). Experimental studies of non-load bearing steel wall systems under fire conditions. *Fire Safety Journal*, *53*, 85–104. https://doi.org/10.1016/j.firesaf.2012.06.009

Kolarkar, P. N. (2010). *Structural and Thermal Performance of Cold-formed Steel Stud Wall Systems under Fire Conditions* (Número September). Queensland University of Technology.

Magarabooshanam, H., Ariyanayagam, A., & Mahendran, M. (2020). Fire resistance of non-load bearing LSF walls with varying cavity depth. *Thin-Walled Structures*, *150*(October 2019). https://doi.org/10.1016/j.tws.2020.106675

Piloto, P. A. G., Gomes, S., Torres, L., Couto, C., & Vila Real, P. (2023). Accuracy of 2D numerical models towards the prediction of the fire resistance on LSF partition walls. *International Journal of Thermal Sciences*, *193*(March), 108511. https://doi.org/10.1016/j.ijthermalsci.2023.108511

Piloto, P. A. G., Khetata, M. S., & Gavilán., A. B. R. (2017). Fire performance of non-loadbearing light steel framing walls - numerical simulation. *7th international conference mechanics and materials in design*, 1603–1610.

Piloto, P. A. G., Khetata, M. S., & Gavilán, A. B. R. (2017). Fire Performance of Non-Loadbearing Light Steel Framing Walls-Numerical and simple calculation methods. *MATTER: International Journal of Science and Technology*, *3*(3), 13–23. https://doi.org/https://dx.doi.org/10.20319/mijst.2017.33.1323 FIRE

Piloto, P. A. G., Khetata, M. S., & Gavilán, A. B. R. (2018). Loadbearıng Capacıty of LSF Walls under Fıre Exposure. *MATTER: International Journal of Science and Technology*, *4*(3), 104–124. https://doi.org/https://dx.doi.org/10.20319/mijst.2018.43.104124

Piloto, P. A. G., Khetata, M. S., & Ramos-Gavilán, A. B. (2022). Analysis of the critical temperature on load bearing LSF walls under fire. *Engineering Structures*, *270*(July), 114858. https://doi.org/10.1016/j.engstruct.2022.114858

Sultan, M. A. (1996). A model for predicting heat transfer through noninsulated unloaded steel-stud gypsum board wall assemblies exposed to fire. *Fire Technology*, *32*(3), 239–259. https://doi.org/10.1007/BF01040217

Torres, L., Couto, C., Vila Real, P., & Piloto, P. (2023). Numerical study of the fire behaviour of external walls in light steel framing. *Fire Safety Journal*, *141*(July), 103946. https://doi.org/10.1016/j.firesaf.2023.103946